

# Correlation dynamics of three spin under a classical dephasing environment

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## Abstract

By starting from the stochastic Hamiltonian of the three correlated spins and modeling their frequency fluctuations as caused by dephasing noisy environments described by Ornstein-Uhlenbeck processes, we study the dynamics of quantum correlations, including entanglement and quantum discord. We prepared initially our open system with Greenberger-Horne-Zeilinger or W state and present the exact solutions for evolution dynamics of entanglement and quantum discord between three spins under both Markovian and non-Markovian regime of this classical noise. By comparison the dynamics of entanglement with that of quantum discord we find that entanglement can be more robust than quantum discord against this noise. It is shown that by considering non-Markovian extensions the survival time of correlations prolong.

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# 1 Introduction

The unavoidable interaction of any realistic quantum system with its environment can destroy coherence between the states of a quantum system. This is decoherence, which can be introduced by various noisy models. Since, this phenomenon is deemed as one of the main obstacles to the realization of quantum information processing, recently, much attention has been paid on influence of it in quantum process [7, 8, 9]. Decoherence dynamics of entanglement and quantum discord, as two very useful resources to perform various quantum tasks, under the influence of environmental noises has been extensively discussed [1, 2, 3, 4, 5, 6, 13, 14, 15, 16]. When the environment correlation time is much shorter than the relaxation time of the system, i.e., environment has no memory, the Markovian approximation can be used to quantified the decoherence dynamics [10, 11, 12]. This approximation simplifies greatly the mathematics to solve the dynamics of open quantum system, but, in truth every environment is non-Markovian, i.e., with memory. The non-Markovian effect is a kind of dynamic backaction effect on the system due to pronounced memory effect of environment which could compensate the lost coherence of quantum system. Preservation of entanglement and discord can be caused by this characteristic of non-Markovian decoherence.

Many investigator have lately used the well-known classical Ornstein-Uhlenbeck (OU) process as a model of non-Markovian decoherence [17, 18, 19]. The OU process has a long history in physics and plays a central role in the mathematical descriptions of Brownian motion and Johnson noise [20, 21]. In this letter, we present the exact solutions for evolution dynamics of entanglement and quantum discord between three spins, initially described by pure Greenberger-Horne-Zeilinger (GHZ) or W state, under the classical OU noise. As expected, the life of entanglement and quantum discord prolong due to the feedback dynamical of non-Markovian decoherence. The aim of this paper is to compare the robustness of entanglement with that of quantum discord against to the OU decoherence. We find that entanglement can be more strong than quantum discord under this noise.

The structure of this article is as follows: First we describe the model of OU decoherence and two correlation measures which we used for this study. In next section we present our results for entanglement and quantum discord between three spins with initial GHZ and W state. Summary of this letter are given in the last section.

## 2 The Model

### 2.1 The Ornstein-Uhlenbeck decoherence

The random fluctuations of a spin-frequency which are sufficiently small, can approximately be described as an OU process [17, 22]. Based on this, the stochastic Hamiltonian of the three correlated spins with random fluctuations frequency

$$H_{tot}(t) = \sum_{i=1}^3 \frac{1}{2} \Omega_i(t) \sigma_z^{(i)}, \quad (2-1)$$

can be assumed as the Hamiltonian of interaction between system and the local OU noise. Under this condition,  $\Omega_i(t)$  which is the independent transition frequency of the  $i$ -th spin, describe the local OU noise with the statistical mean value properties as

$$\begin{aligned} M[\Omega_i(t)] &= 0, \\ M[\Omega_i(s)\Omega_i(t)] &= \beta(s-t) = \frac{1}{2} \Gamma_i \gamma e^{-\gamma|s-t|}. \end{aligned} \quad (2-2)$$

In this classical noise,  $\gamma$  is the bandwidth of the noise, which is related to the correlation time as  $\tau_c = \frac{1}{\gamma}$ . Figuratively, the correlation time can be deemed as the time scale over which the environment has memory and after it the environment is back to equilibrium and effectively has no memory. The coupling strength between the  $i$ -th spin and the environment is given by  $\Gamma_i$ , ( $i = 1, 2, 3$ ), which for simplicity we assumed  $\Gamma_i = \Gamma$  for all spins.

The time evolution of the total system can be calculated explicitly from

$$\rho_{tot}(t) = U(t) \rho_{tot}(0) U^\dagger(t), \quad (2-3)$$

where the stochastic unitary operator  $U(t)$  is the explicit solution for the stochastic Schrodinger equation as

$$U(t) = e^{-i \int_0^t H_{tot}(s) ds}. \quad (2-4)$$

Clearly, the unitary operator  $U(t)$  is dependent on the noise. By taking the ensemble average over the noise field, ( i.e., from the statistical mean ) the reduced density matrix of open spins system  $\rho_s(t)$  is obtained

$$\rho_s(t) = M[\rho_{tot}(t)]. \quad (2-5)$$

So, the dynamics of the system density matrix can be described in terms of Kraus representation as

$$\rho_s(t) = \sum_i K_i(t) \rho_s(0) K_i^\dagger(t). \quad (2-6)$$

By using the fact that  $\text{Tr}[\rho_s(t)] = 1$ , a condition on the Kraus operators can be obtained as  $\sum_i K_i^\dagger(t) K_i(t) = I$ . In our case, the Kraus operators describing the interaction with the local OU noise are given by

$$\begin{aligned} K_1 &= F_1 \otimes F_1 \otimes F_1, & K_2 &= F_1 \otimes F_1 \otimes F_2, & K_3 &= F_1 \otimes F_2 \otimes F_1, & K_4 &= F_2 \otimes F_1 \otimes F_1, \\ K_5 &= F_1 \otimes F_2 \otimes F_2, & K_6 &= F_2 \otimes F_1 \otimes F_2, & K_7 &= F_2 \otimes F_2 \otimes F_1, & K_8 &= F_2 \otimes F_2 \otimes F_2, \end{aligned} \quad (2-7)$$

where

$$F_1 = \begin{pmatrix} \mu(t) & 0 \\ 0 & 1 \end{pmatrix}, \quad F_2 = \begin{pmatrix} \nu(t) & 0 \\ 0 & 0 \end{pmatrix}. \quad (2-8)$$

The parameters appearing in  $F_1$  and  $F_2$  operators are

$$\begin{aligned} \mu(t) &= \exp\left[\int_0^t \beta(s-t) d^2s\right] = \exp\left[\frac{-\Gamma}{2}\left\{t + \frac{1}{\gamma}(e^{-\gamma t} - 1)\right\}\right], \\ \nu(t) &= \sqrt{1 - \mu^2(t)}. \end{aligned} \quad (2-9)$$

For sufficiently large values of bandwidth,  $\gamma \rightarrow \infty$ , i.e., the correlation time  $\tau_c \rightarrow 0$ , we get  $\beta(s-t) = \Gamma\delta(s-t)$ , and hence the Markovian dynamic of OU noise is recovered. For this limit, the factor of decoherence is reduced to  $\mu(t) \rightarrow \exp[\frac{-\Gamma t}{2}]$ , hence, the coherence decay rate determine by the coupling strength between the spins and environment  $\Gamma$ . If the dynamics of system and environment is such that the correlation function in Eq. (2) can not be replaced by a delta function, (i.e.,  $\gamma \rightarrow 0$ ), the dynamics is non-Markovian and memory effects of the environment have important roles. In this case, by using the approximation  $e^{-\gamma t} \simeq 1 - \gamma t + \frac{1}{2}(\gamma t)^2$ , the factor of decoherence, can be expanded as  $\mu(t) \rightarrow \exp[\frac{-1}{4}\gamma\Gamma t^2]$ .

## 2.2 Measuring entanglement

Since entanglement is conceived as a resource to perform various tasks of quantum information processing [23, 24, 25, 26], knowledge about the amount of entanglement in a quantum state is so important. Indeed, awareness from the value of entanglement, means knowing how well a certain task can be accomplished. The quantification problem of entanglement only for bipartite systems in pure states [27] and two-qubit system in mixed state [28] is essentially solved. In multi-partite systems, even the pure state case, this problem is not exactly solved and just lower bounds for the entanglement have been proposed [29, 30, 31, 32]. Here, in order to determination the exact minimum of entanglement between three spins, we use the lower

bound of concurrence for three-qubit state which is recently suggested by Li et al. [33]

$$\tau_3(\rho) = \frac{1}{\sqrt{3}} \left( \sum_{j=1}^6 (C_j^{12|3})^2 + (C_j^{13|2})^2 + (C_j^{23|1})^2 \right)^{\frac{1}{2}}, \quad (2-10)$$

where  $C_j^{12|3}$  is terms of the bipartite concurrences for qubits 12 and 3 which is given by

$$C_j^{12|3} = \max\{0, \lambda_j^{12|3}(1) - \lambda_j^{12|3}(2) - \lambda_j^{12|3}(3) - \lambda_j^{12|3}(4)\}. \quad (2-11)$$

In this notation,  $\lambda_j^{12|3}(\kappa)$ , ( $\kappa = 1..4$ ), are the square nonzero roots, in decreasing order, of the non-Hermitian matrix  $\rho \tilde{\rho}_j^{12|3}$ . The matrix  $\tilde{\rho}_j^{12|3}$  are obtained from rotated the complex conjugate of density operator,  $\rho^*$ , by the operator  $S_j^{12|3}$  as  $\tilde{\rho}_j^{12|3} = S_j^{12|3} \rho^* S_j^{12|3}$ . The rotation operators  $S_j^{12|3}$  are given by tensor product of the six generators of the group SO(4), ( $L_j^{12}$ ), and the single generator of the group SO(2), ( $L_0^3$ ) that is  $S_j^{12|3} = L_j^{12} \otimes L_0^3$ . Since the matrix  $S_j^{12|3}$  has four rows and columns which are identically zero, so the rank of non-Hermitian matrix  $\rho \tilde{\rho}_j^{12|3}$  can not be larger than 4, i.e.,  $\lambda_j^{12|3}(\kappa) = 0$  for  $\kappa \geq 5$ . The bipartite concurrences  $C^{13|2}$  and  $C^{23|1}$  are defined in a similar way to  $C^{12|3}$ .

## 2.3 Measuring quantum discord

Another kind of quantum correlation which is in general different from entanglement has been designated as quantum discord [34]. This measure of quantum correlation, which is arising from the difference between two quantum extensions of the classical mutual information, proved its abilities as a fundamental resource for quantum information tasks [35, 36, 37, 38]. Recently, many efforts to generalization of quantum discord to multi-partite systems have been made by different authors [39, 40]. The global measure of quantum discord which is obtained by a systematic extension of the bipartite quantum discord is the result of such efforts [41]. By using this measure one can quantifies the quantum discord of an arbitrary multi-partite state.

Under a set of von-Neumann measurements as

$$\begin{aligned} \Pi_1^{(l)} &= \begin{pmatrix} \cos^2(\frac{\theta_l}{2}) & e^{i\varphi_l} \cos(\frac{\theta_l}{2}) \sin(\frac{\theta_l}{2}) \\ e^{-i\varphi_l} \cos(\frac{\theta_l}{2}) \sin(\frac{\theta_l}{2}) & \sin^2(\frac{\theta_l}{2}) \end{pmatrix}, \\ \Pi_2^{(l)} &= \begin{pmatrix} \sin^2(\frac{\theta_l}{2}) & -e^{-i\varphi_l} \cos(\frac{\theta_l}{2}) \sin(\frac{\theta_l}{2}) \\ -e^{i\varphi_l} \cos(\frac{\theta_l}{2}) \sin(\frac{\theta_l}{2}) & \cos^2(\frac{\theta_l}{2}) \end{pmatrix}, \end{aligned} \quad (2-12)$$

which rotated the direction of the basis vector of  $l$ -th spin with  $\theta_l \in [0, \pi)$  and  $\varphi_l \in [0, 2\pi)$ , the global quantum discord has the form

$$D(\rho) = \min_{\{\theta_l, \varphi_l\}} [S(\rho \| \Phi(\rho)) - \sum_{l=1}^3 S(\rho_{(l)} \| \Phi^{(l)}(\rho_l))]$$

$$= \min_{\{\theta_l, \varphi_l\}} [S(\Phi(\rho)) - S(\rho) - \sum_{l=1}^3 (S(\Phi^{(l)}(\rho_l)) - S(\rho_l))]. \quad (2-13)$$

In this notation,  $S(\rho) = -\text{Tr}[\rho \log_2 \rho]$  is the von-Neumann entropy of the density matrix and  $\Phi^{(l)}(\rho_l) = \Pi_1^{(l)} \rho_l \Pi_1^{(l)} + \Pi_2^{(l)} \rho_l \Pi_2^{(l)}$  is the reduce density matrix after performing the measurement on the  $l$ -th spin. The matrix  $\Phi(\rho)$  obtain by carrying out the 8 projective measurements

$$\begin{aligned} \Pi_1 &= \Pi_1^{(1)} \otimes \Pi_1^{(2)} \otimes \Pi_1^{(3)}, & \Pi_2 &= \Pi_1^{(1)} \otimes \Pi_1^{(2)} \otimes \Pi_2^{(3)}, & \Pi_3 &= \Pi_1^{(1)} \otimes \Pi_2^{(2)} \otimes \Pi_1^{(3)}, \\ \Pi_4 &= \Pi_2^{(1)} \otimes \Pi_1^{(2)} \otimes \Pi_1^{(3)}, & \Pi_5 &= \Pi_1^{(1)} \otimes \Pi_2^{(2)} \otimes \Pi_2^{(3)}, & \Pi_6 &= \Pi_2^{(1)} \otimes \Pi_1^{(2)} \otimes \Pi_2^{(3)}, \\ \Pi_7 &= \Pi_2^{(1)} \otimes \Pi_2^{(2)} \otimes \Pi_1^{(3)}, & \Pi_8 &= \Pi_2^{(1)} \otimes \Pi_2^{(2)} \otimes \Pi_2^{(3)}, \end{aligned} \quad (2-14)$$

on the three correlated spins as:  $\Phi(\rho) = \sum_{m=1}^8 \Pi_m \rho \Pi_m$ . In order to eliminate the dependence of quantum discord on the measurement operators, we must find the measurement basis that minimizes  $D(\rho)$ .

In the following we will investigated the evolution of entanglement and quantum discord, as two different kinds of the quantum correlation, between three correlated spin which initially described by pure GHZ or W state under the OU Markovian and non-Markovian decoherences.

### 3 The dynamics of three correlated spins under the OU noise

In this section we present time evolution of entanglement and discord between three spins which is coupled with OU classical noise. We assume the open system is initially prepared in inequivalent class of pure three qubit state with maximally quantum correlation which is known as GHZ and W states.

#### 3.1 Initial GHZ state

First, we suppose that the initial state of the system is pure GHZ state

$$|GHZ\rangle = \frac{1}{\sqrt{2}}(|000\rangle + |111\rangle). \quad (3-15)$$

According to Eq. (6), the reduced density matrix of the system under the OU decoherence can be expressed as

$$\rho_{GHZ}(t) = \frac{1}{2} \{ |000\rangle\langle 000| + |111\rangle\langle 111| \} + \frac{\mu^3(t)}{2} \{ |000\rangle\langle 111| + |111\rangle\langle 000| \}.$$

$$(3-16)$$

The concurrence of the above density matrix can be easily computed as

$$\tau_3(\rho_{GHZ}(t)) = \mu^3(t)\tau_3(\rho_{GHZ}(0)). \quad (3-17)$$

Now, we turn to calculating the quantum discord from Eq. (13). By tracing out any two spins of the density matrix (16), one can obtain the reduced density matrices of the subsystems as  $\rho_1 = \rho_2 = \rho_3 = \frac{I}{2}$ . So,  $\sum_{l=1}^3 (S(\Phi^{(l)}(\rho_l)) - S(\rho_l)) = 0$ . The von-Neumann entropy of the  $\rho_{GHZ}(t)$  can be computed as

$$S(\rho_{GHZ}(t)) = 1 - \frac{1 + \mu^3(t)}{2} \log_2(1 + \mu^3(t)) - \frac{1 - \mu^3(t)}{2} \log_2(1 - \mu^3(t)). \quad (3-18)$$

After some calculation to find the desired measurement basis which minimizes the quantum discord, we deduced that the eigenbasis of the Pauli matrix  $\sigma_z$  are the best measurement basis. Under this local measurement we obtain  $S(\Phi(\rho_{GHZ}(t))) = 1$  and

$$D(\rho_{GHZ}(t)) = \frac{1 + \mu^3(t)}{2} \log_2(1 + \mu^3(t)) + \frac{1 - \mu^3(t)}{2} \log_2(1 - \mu^3(t)). \quad (3-19)$$

In order to comparison the robustness of the entanglement (17) and the quantum discord (19) against to OU decoherence, we plot these quantities as a function of the dimensionless scale  $\Gamma t$  for both Markovian (a) and non-Markovian (b) regime in Fig. 1. It is explicit that, entanglement can be survived under the Markovian and non-Markovian conditions more than the quantum discord. Moreover, observe that due to the influence of memory effect of environment the entanglement and the quantum discord have longer life. In the other words, one could imagine that non-Markovian effect is a key factor to preserve quantum correlation since non-Markovian effect is a kind of backaction effect which could compensate the lost coherence of quantum system.

### 3.2 Initial W state

When the three correlated spins is initially prepared in the W state

$$|W\rangle = \frac{1}{2}(|100\rangle + |010\rangle + \sqrt{2}|001\rangle), \quad (3-20)$$

the density matrix dynamics, according Eq. (6), can be express as

$$\rho_W(t) = \frac{1}{4} \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & \sqrt{2}\mu^2(t) & 0 & \sqrt{2}\mu^2(t) & 0 & 0 & 0 \\ 0 & \sqrt{2}\mu^2(t) & 1 & 0 & \mu^2(t) & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sqrt{2}\mu^2(t) & \mu^2(t) & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}. \quad (3-21)$$

From the lower bound of concurrence for three-qubit state Eq. (10) for the above matrix we obtain

$$\tau_3(\rho_W(t)) = \mu^2(t)\tau_3(\rho_W(0)). \quad (3-22)$$

In order to determine quantum discord according to Eq. (13), we first evaluate the one-spin density matrices representing the individual subsystems by tracing out two spins. These reduce density matrices have the flowing form  $\rho_1 = \rho_2 = \rho_3 = \frac{1}{4}\{3|0\rangle\langle 0| + |1\rangle\langle 1|\}$ . Next, by using the same procedure done in previous section to find the desired measurement basis which minimizes the quantum discord, we obtain the minimum of quantum discord with adopt local measurements in the  $\sigma_z$  eigenbasis for any spin. Under such measurements the state of the single spin is not induced therefor we have  $\sum_{l=1}^3 (S(\Phi^{(l)}(\rho_l)) - S(\rho_l)) = 0$  and  $S(\Phi(\rho_W(t))) = \frac{3}{2}$ . Finally, by inserting the von-Neumann entropy of the time-dependent reduced density matrix for three correlated spins in Eq. (13), we obtain the flowing form for quantum discord

$$\begin{aligned} D(\rho_W(t)) &= \frac{-1}{4}(5 + \mu^2(t)) + \frac{1}{4}(1 - \mu^2(t)) \log_2(1 - \mu^2(t)) \\ &+ \frac{1}{8} \{ (3 + \mu^2(t) - \sqrt{1 - 2\mu^2(t) + 17\mu^4(t)}) \\ &\quad \log_2(3 + \mu^2(t) - \sqrt{1 - 2\mu^2(t) + 17\mu^4(t)}) \\ &+ (3 + \mu^2(t) + \sqrt{1 - 2\mu^2(t) + 17\mu^4(t)}) \\ &\quad \log_2(3 + \mu^2(t) + \sqrt{1 - 2\mu^2(t) + 17\mu^4(t)}) \}. \end{aligned} \quad (3-23)$$

Notice that we shall re-normalize the Eq. (23) in such a way that we have  $D(\rho_W(0)) = 1$ . From the expressions of entanglement (22) and quantum discord (23), it can be found that for  $\mu(t) \rightarrow 0$  quantum correlation between three spins disappear. In Fig. 2, the dynamics of these quantities for both Markovian (a) and non-Markovian (b) dynamics are illustrated. Clearly, robustness of entanglement versus OU Markovian and non-Markovian decoherence is



more than quantum discord.

Notice that, since the factor of decoherence  $\mu(t)$  appears as quadratic in quantum correlation of W state, this state has life longer than GHZ state with cubic decoherence. Comparison of plots in Fig. 1 and Fig. 2 justifies this fact.

## 4 Summary

In summary, we have investigated the exact decoherence dynamics of quantum correlations, including entanglement and quantum discord, between three correlated spin with initial GHZ and W state under a local dissipative OU process. By studying both Markovian and non-Markovian regime of this classical noise, we have found that under Markovian dynamics quantum correlation suffers sudden death, while due to the influence of memory effect of environment in non-Markovian dynamics, it has longer life. Moreover, comparison of the survival time of entanglement and quantum discord make it clear that against dephasing OU decoherence, entanglement is more robust than quantum discord, because it decays exponentially while the discord of the same state decays logarithmic. Also, our results have shown that W state has strong dynamics under decoherence than GHZ state.

## References

## References

- [1] Li J. G., Zou J., and Shao B., *Phy. Rev. A* **82**, 042318 (2010).
- [2] Yu T. and Eberly J.H., *Opt. Commun.* 264, 393397 (2006).
- [3] Yu T. and Eberly J.H., *Opt. Commun.* 283, 676680 (2010).
- [4] Tong Q. J., An J. H., Luo H. G., and Oh C. H., *Quantum Inf. Comput.* 11, 0874 (2011).
- [5] Ikram M., Li F. l., and Suhail Zubairy M., *Phy. Rev. A* **75**, 062336 (2007).
- [6] Werlang T., Souza S., Fanchini F. F., and Villas-Bôas C. J., *Phys. Rev. A* **80**, 024103 (2009).
- [7] Chen Q., and Feng M., *Phys. Rev. A* **82**, 052329 (2010)

- [8] Imamoglu A., Awschalom D. D., Burkard G., DiVincenzo D. P., Loss D., Sherwin M., and Small A., Phys. Rev. Lett. **83**, 42044207 (1999).
- [9] Zheng S. B., and Guo G. C., Phys. Rev. Lett. **85**, 23922395 (2000).
- [10] Breuer H. P. and Petruccione F., The Theory of Open Quantum Systems (Oxford University Press, Oxford, 2002).
- [11] Lindblad G., Commun. Math. Phys. **48** 119 (1976).
- [12] H.-P. Breuer, E.-M. Laine, and J. Piilo, Phys. Rev. Lett. **103**, 210401 (2009).
- [13] Fanchini F. F., Castelano L. K. and Caldeira A. O., New J. Phys. **12** 073009 (2010).
- [14] Altintas F., and Eryigit R., Physics Letters A **374**, 4283-4296 (2010).
- [15] Wang B., Xu Z. Y., Chen Z. Q., and Feng M., Phys. Rev. A **81**, 014101 (2010).
- [16] Werlang T., and Rigolin G., Phys. Rev. A **81**, 044101 (2010).
- [17] Yu t. and Eberly J. H., Opt. Commun. **283**, 676 (2010).
- [18] Barchielli A., Pellegrini C., and Petruccione F., EPL **91**, 24001 (2010)
- [19] Xu Guo-Fu and Tong Dian-Min, Chinese Phys. Lett. **28**, 060305 (2011).
- [20] Uhlenbeck G.E., and Ornstein L.S., Phys. Rev. **36**, 823 (1930).
- [21] Tsekov R., Ann. Univ. Sofia, Fac. Chem. **88**(1), 57 (1995).
- [22] Gillespie D. T., Phys. Rev. E **54**, 2084 (1996).
- [23] Bennett C. H., Brassard G., Crepeau C., Jozsa R., Peres A., and Wootters W. K., Phys. Rev. Lett. **70**, 1895 (1993).
- [24] Bennett C. H., and Wiesner S. J., Phys. Rev. Lett. **69**, 2881 (1992).
- [25] Ekert A. K., Phys. Rev. Lett. **67**, 661 (1991).
- [26] Barenco A., Deutsch D., Ekert A., and Jozsa R., Phys. Rev. Lett. **74**, 4083 (1983).
- [27] Bennett C. H., Brenstein H. J., Popescu S., and Schumacher B., Phys. Rec. A **53**, 2046 (1996).

- [28] Wootters W.K., Phys. Rev. Lett. **80**, 2245 (1998).
- [29] Mintert F., Kus M., and Buchleitner A., Phys. Rev. Lett. **92**, 167902 (2004).
- [30] Gerjuoy E., Phys. Rev. A **67**, 052308 (2003).
- [31] Gao X. H., Fei S. M., and Wu K., Phys. Rev. A **74**, 050303(R) (2006).
- [32] Ou Y. C. , Fan H., and Fei S. M., Phys. Rev. A **78**, 012311 (2008).
- [33] Li M., Fei S. M., and Wang Z. X., J. Phys. A: Math. Theor. **42**, 145303 (2009).
- [34] Ollivier H., and Zurek W. H., Phys. Rev. Lett. **88**, 017901 (2002).
- [35] Datta A., Shaji A. and Caves C. M., Phys. Rev. Lett. **100**, 050502 (2008).
- [36] Sarandy M. S., Phys. Rev. A **80**, 022108 (2009).
- [37] Dillenschneider R., Phys. Rev. B **78**, 224413 (2008).
- [38] Cui J. and Fan H., J. Phys. A: Math. Theor. **43**, 045305 (2010).
- [39] Modi K., Paterek T., Son W., Vedral V., and Williamson M., Phys. Rev. Lett. **104**, 080501 (2010).
- [40] Okrasa M., and Walczak Z., arXiv: 1101.6057 (2011).
- [41] Rulli C. C., and Sarandy M. S., Phys. Rev. A **84**, 042109 (2011).

Figure 1: (Color online) Entanglement (solid blue) and quantum discord (dashed red) dynamics of three correlated spin with initial GHZ stat under OU decoherence. Here, we have chosen the parameters  $\Gamma = 1$ . Fig. (a) corresponds to Markovian regime with  $\mu(t) \rightarrow \exp[\frac{-\Gamma t}{2}]$  and Fig. (b) to non-Markovian regime with  $\mu(t) \rightarrow \exp[\frac{-1}{4}\gamma\Gamma t^2]$  and  $\gamma = 0.01$ .

Figure 2: (Color online) Entanglement (solid blue) and quantum discord (dashed red) dynamics of three correlated spin with initial W stat under OU decoherence. Here, we have chosen the parameters  $\Gamma = 1$ . Fig. (a) corresponds to Markovian regime with  $\mu(t) \rightarrow \exp[\frac{-\Gamma t}{2}]$  and Fig. (b) to non-Markovian regime with  $\mu(t) \rightarrow \exp[\frac{-1}{4}\gamma\Gamma t^2]$  and  $\gamma = 0.01$ .